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DISCOVERY

Behaviour of chemically reacting in compressible fluids in electromagnetic fields provoked by radiation

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ABSTRACT
Application of radiation and first order chemical reaction to the behavior of fluids in electromagnetic fields is investigated analytically. The study reveals that the behavior of fluids in electromagnetic fields is governed by electrical conductivity which gives rise to electromagnetic forces and mechanical forces. The effect of electrical conductivity decreases the magnetic field and increases the electric field while increase in the electrical resistivity, increase magnetic field strength and decrease the electric field strength. Critical observations also reveal that increase in the flow of energy, decreases the heat transfer coefficient and increase in the chemical reaction term results in a decrease in the mass transfer coefficient.

Keywords: Electrical conductivity, Electromagnetic fields, Chemical reaction, Radiation, Homotopy perturbation method

1. INTRODUCTION

Fluid in physics is made up of liquids and gases. Life as we know it would not exist without fluids and without the behaviour of fluids. Essentially, when fluid is introduced into an electromagnetic field, it is primarily governed by electrical conductivity. This effect gives rise to not only electromagnetic forces but mechanical forces as well. An alternating magnetic field applied to a conducting fluid will induce electric currents in the fluid and hence a Lorentz force distribution. The Lorentz force is rotational and is set into motion. This assertion was corroborated by Branover [1] and he went further to say that electromagnetic field exists everywhere on the earth's surface and several studies on its influence are abounded. In a work Published by Eisenschitz and Cole [2], they opined that if an insulating liquid is placed between the plates of a condenser, the electric field gives rise to induced intermolecular forces which are proportional to the square of the field strength. Symons [3] investigated that fluid is unique but not anomalous and reported that, it appears that electric and magnetic fields have opposite effects on fluid clustering. Colic and Morse [4], in the elusive mechanism of the magnetic memory of water, suggested that, in addition to the breakage of hydrogen bonds, electromagnetic fields may perturb the gas/liquid interface and produce reaction oxygen species. Zhang et al [5], studied the behaviour of dielectric liquids in electric field and reported that, a silicon oil is subjected to electric field and the result using the Ohnesorge number revealed that due to the low electrical conductivity and low electrical relaxation time of the silicon oils, only unsteady transient jets were found. Ninno and Castellano [6], in their findings, reported that extremely low frequency electromagnetic fields have significant and lasting effects on liquid water. Using a weak field, adjusted to give a magnetic field of 45 micro Tesla on glutamic acid solution cause changes in the pH shifting towards the de-pronated species. Sherwood [7] in his study of fluid droplets in electric and magnetic fields reported that, a fluid held by surface tension will deform when an electric or magnetic field is applied and depend largely on permittivity/permeability and conductivity of the drop and of the surrounding fluid. Zanh and Pioch [8], reported that analyses and measurement have shown anomalous behaviour of ferro fluids in alternating magnetic fields, this they investigated by pumping ferro fluid which the flow direction can reverse as a function of magnetic field amplitude, frequency and direction. In a research carried out by Daniel [9], a new generation of magnetic sensitive ionic liquids-magnetic ionic liquids, exhibiting a strong response to a magnetic field was developed. This shows that its physical properties are influenced by the presence of an applied magnetic field. Several studies are also abounded in the behaviuor of fluids on non electromagnetic forces. Few are Prasad and Bhaskar [10], Ferdows et al., [11], Hayat et al., [12], Subhakar and Gangadhar [13], Shivaiah and Anand [14] and Gnaneswara and Bhaskar [15], all studied the effect of similar and different non-electromagnetic forces on the behaviour of different types of fluid and made far reaching suggestions. The aim of this study is to consider the effect of electromagnetic forces and mechanical forces on fluid flow with emphasis on radiation and chemical reaction as non electromagnetic forces. This combination of forces caused by electrical conductivity on the behaviour of fluid in electromagnetic field is an extension of the literatures cited.

2. FORMALISM

The equation of continuity

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho v) = 0 \qquad (1)$$

The momentum equation

$$\rho \frac{\partial v}{\partial t} = -\nabla p - (JXB) + \mu \nabla^2 v + \rho g \qquad (2)$$

Maxwell's equations

$$\nabla x E = -\frac{\partial B}{\partial t} \qquad (3)$$

$$\nabla x H = J + \frac{\partial D}{\partial t} \qquad (4)$$

Ohm's law for a one component conducting fluid

$$J = \sigma(E + vxB) \qquad (5)$$

Experimental law of Gauss for magnetic field

$$\nabla.B = 0 \qquad (6)$$

Supplementary equations (constitutive relations) in isotropic medium

$$D = \varepsilon_0 E \tag{7}$$

$$H = \frac{1}{\mu_0} B \tag{8}$$

The energy equation

$$\rho C_p \frac{\partial T}{\partial y} = k \frac{\partial^2 T}{\partial y^2} - \frac{\partial q_y}{\partial y} \tag{9}$$

The concentration equation

$$\rho C_p \frac{\partial C}{\partial y} = D \frac{\partial^2 C}{\partial y^2} - k_r^2 C \tag{10}$$

Considering the Boussinesq approximation in the body force to incorporate the temperature dependent density and concentration dependent density, equation (2) can be written as

$$\rho \frac{\partial \dot{u}}{\partial \dot{t}} = -\nabla p - (JXB) + \mu \nabla^2 \dot{u} + \rho g \beta (T - T_0) + \rho g \beta * (C - C_0) \tag{11}$$

with the boundary conditions

$$\dot{u} = 1,\ T = 1,\ \dot{C} = 1 \text{ at } \dot{y} = 0 \tag{12}$$

$$\dot{u} \to 0,\ T \to 0,\ \dot{C} \to 0 \text{ at } \dot{y} \to 1$$

In order to consider the effect of radiation on an optically thick model in which the thermal layer becomes very thick or highly absorbing as described by Rosseland approximation, Cogley et al [16] as

$$\frac{\partial q_r}{\partial \dot{y}} = -\frac{4\zeta}{3\alpha} \frac{\partial^2 T^4}{\partial \dot{y}^2} \tag{13}$$

where ρ_x is free charge density, J is free current density, E is electric strength, B is magnetic induction, H is magnetic strength, ε_0 is permittivity of free space, μ_0 is permeability of free space, $\dot{u}$ and v are velocities and $\dot{x}$, $\dot{y}$ directions, t' is time, C is fluid concentration, p is pressure, ρ is density of fluid, μ is viscosity of fluid, σ is electrical conductivity of fluid, B is imposed magnetic induction, g is acceleration due to gravity, β is thermal expansion due to temperature, β^* is thermal expansion due to concentration, T is temperature of fluid, T_∞ is free stream temperature, C_∞ is free stream concentration, k is thermal conductivity of fluid, C_p is specific heat at constant pressure, q_r is radiation term, C_s is concentration susceptivity, T_m is mean nanofluid temperature k_r^2 is chemical reaction term, D is chemical molecular diffusivity, ζ is the Stefan-Boltzmann constant and α is the absorption coefficient. If temperature difference within the flow of the fluid is sufficiently small, we can approximate T^4 using Taylor series expansion about 0 and obtain

$$T^4 = 4T_\infty^3 T - 3T_\infty^4 \tag{14}$$

Using equation (3), the time dependence of magnetic field is

$$\frac{\partial B}{\partial t} = -(\nabla x E) \tag{15}$$

Equation (5) is put into equation (14) and the result is

$$\frac{\partial B}{\partial t} = -\nabla(vxB) - \nabla x\left(\frac{J}{\sigma}\right) \tag{16}$$

Neglecting the displacement current in equation (4) and using equation (7), equation (15) becomes

$$\frac{\partial B}{\partial t} = \nabla(vxB) + \frac{1}{\mu_0 \sigma} \nabla x(\nabla x B) \tag{17}$$

Simplifying, using equation (6), equation (17) reduced to the form

$$\frac{\partial B}{\partial t} = \nabla(vxB) + \frac{1}{\mu_0 \sigma}\nabla^2 B \quad (18)$$

If the fluid is at rest, then equation (18) reduced to

$$\frac{\partial B}{\partial t} = \frac{1}{\mu_0 \sigma}\nabla^2 B \quad (19)$$

with the boundary conditions

$$B(0,t) = B(\pi,t) = 0 \qquad B(y,0) = 1 \quad (20)$$

Method of solution

One dimension of equation (19) is assumed and taking the finite Fourier Sine Transform on both sides, the expression takes the form

$$\int_0^\pi \frac{\partial B(y,t)}{\partial t} Sinnydy = \frac{1}{\mu_0 \sigma}\int_0^\pi \frac{\partial^2 B(y,t)}{\partial y^2} Sinnydy \quad (21)$$

where n is an integer

Let $B_0(n,t) = \int_0^\pi B(y,t) Sinnydy$, then

$$\frac{dB_0(n,t)}{dt} = \int_0^\pi \frac{\partial B(x,t)}{\partial t} Sinnydy = \frac{1}{\mu_0 \sigma}\int_0^\pi \frac{\partial^2 B(x,t)}{\partial y^2} Sinnydy \quad (22)$$

Simplifying and imposing the boundary conditions, equation (22) reduced to

$$B_0(n,t) = \left(\frac{1 - Cosn\pi}{\mu_0 \sigma n}\right) Cosn\pi e^{-n^2 t} \quad (23)$$

Applying the inversion formula for finite Fourier Sine Transform, following Gupta [17], equation (23) is written as

$$B(y,t) = \frac{2}{\pi}\sum_{n=1}^{\infty}\left(\left(\frac{1 - Cons\pi}{\mu_0 \sigma n}\right) Cosn\pi e^{-n^2 t}\right) Sinny \quad (24)$$

If the conductivity is very large or infinite, equation (18) reduced to

$$\frac{\partial B}{\partial t} = \nabla(vxB) \quad (25)$$

To determine an expression for the electric field intensity, equation (5) is put into equation (15) and the expression takes the form

$$\frac{1}{\sigma v}\frac{\partial J}{\partial t} - \frac{1}{v}\frac{\partial E}{\partial t} = -\nabla xE \quad (26)$$

$\frac{\partial}{\partial t}$ is taken on equation (4) and also taking into consideration $\nabla xB = \mu_0 J$ as well as the constitutive relation of equation (7), equation (26) will transform into

$$\frac{\partial^2 E}{\partial t^2} = \frac{\sigma v}{\varepsilon_0}\frac{\partial E}{\partial y} \quad (27)$$

with the boundary conditions $E(y,0) = E(y,\pi) = 1 \quad E(0,t) = 1$ (28)

Using the method of separating the variables and imposing the boundary conditions of equation (28), the solution of equation (27) is written as

$$E(y,t) = Cosk_s tExp - \left(\frac{\varepsilon_0}{\sigma v} k_s^2 y\right) \tag{29}$$

where k_s is a constant

Equation (25) shows that the magnetic lines of force are in motion with fluid velocity and that the magnetic flux through any circuit moving with fluid velocity is constant in time. Also, equation (11) and the use of equation (5) can be written as

$$\rho \frac{\partial v}{\partial t} = F - \sigma\left(E + (vxB)\right)xB \tag{30}$$

where F is the sum of all the non-electromagnetic forces only. Simplification of equation (30) and for fluids of infinite conductivity, it reduced to

$$\rho \frac{\partial v}{\partial t} = F \tag{31}$$

This shows that flow parallel to B is governed by non-electromagnetic forces only, which is the mechanical behaviour of the system.

To tackle the effect of mechanical forces imposed on the system, equations (9)-(12) are transform into dimensionless form. The dimensionless quantities used are

$$\begin{gathered} u = \frac{\dot{u}}{\dot{x}\dot{t}}, y = \frac{\dot{y}}{\dot{x}}, t = \frac{\dot{t}}{\dot{u}\dot{y}}, \mathrm{Re} = \frac{\mu \dot{C}}{v_0 \rho}, \theta = \frac{T - T_\infty}{T_b - T_\infty}, C = \frac{\dot{C} - C_\infty}{C_b - C_\infty} \\ \mathrm{Pr} = \frac{v(\rho C_p)}{k}, \frac{\partial p}{\partial \dot{x}} = P, Sc = \frac{\mu}{D}, k_0 = \frac{k_r^2 \mu}{v'^2},, N = \frac{16\zeta T_\infty^3}{3\alpha(C_p)} \\ Gr_T = \frac{g\beta(T - T_\infty)\mu}{v_0 \dot{u}^2}, Gr_C = \frac{g\beta^*(\dot{C} - C_\infty)\mu}{v_0 \dot{u}^2} \end{gathered} \tag{32}$$

By using the dimensionless quantities, the governing hydrodynamic equations are transformed into the form

$$\frac{\partial u}{\partial t} = -P + \frac{1}{\mathrm{Re}} \frac{\partial^2 u}{\partial y^2} + Gr_T \theta + Gr_C C \tag{33}$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{\mathrm{Pr}} \frac{\partial^2 \theta}{\partial y^2} - N\theta \tag{34}$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc} \frac{\partial^2 C}{\partial y^2} - k_0 C \tag{35}$$

and the boundary conditions are

$$\begin{gathered} u = 1,\ \theta = 1,\ C = 1 \text{ at } y = 0 \\ u \to 0,\ \theta \to 0,\ C \to 0 \text{ at } y \to 1 \end{gathered} \tag{36}$$

where Re is the Reynolds number, Pr is Prandtl number, Sc is Schmidt number, Gr_T is Grashof number due to temperature, Gr_C is Grashof number due to concentration, N is dimensionless radiation term, k_0 is dimensionless chemical reaction term, θ is dimensionless temperature, C is dimensionless concentration.

Solution Technique

The solution to equations (33) – (35), assumed the form

$$u = U(y)e^{-nt},\ \theta = \phi(y)e^{-nt},\ C = \psi(y)e^{-nt},\ \ P = P_x(y)e^{-nt} \tag{37}$$

Substituting equation (37) into equations (33) – (35) reduced to

$$\mathrm{Re}^{-1}U''(y)+nU(y)+Gr_T\phi(y)+Gr_C\psi(y)-P_x=0 \quad (38)$$

$$\mathrm{Pr}^{-1}\phi''(y)+(n-N)\phi(y)=0 \quad (39)$$

$$Sc^{-1}\psi''(y)+(n-k_0)\psi(y)=0 \quad (40)$$

with the boundary conditions

$$U=e^{nt},\ \phi=e^{nt},\ \psi=e^{nt}\ \text{at}\ y=0$$

$$U\to 0,\ \phi\to 0,\ \psi\to 0\ \text{at}\ y\to 1 \quad (41)$$

To solve equations (38) - (40), Homotopy Pertubation Method as used by He ([18] – [20]) is applied as follows

$$H(U,p)=(1-p)\left[\mathrm{Re}^{-1}U''(y)\right]+p\left[\mathrm{Re}^{-1}U''(y)+nU(y)+Gr_T\phi(y)+Gr_C\psi(y)-P_x\right]=0 \quad (42)$$

$$H(\phi,p)=(1-p)\left[\mathrm{Pr}^{-1}\phi''(y)\right]+p\left[\mathrm{Pr}^{-1}\phi''(y)+(n-N)\phi(y)\right]=0 \quad (43)$$

$$H(\psi,p)=(1-p)\left[Sc^{-1}\psi''(y)\right]+p\left[Sc^{-1}\psi''(y)+(n-k_0)\psi(y)\right]=0 \quad (44)$$

Assume the solution to equations (42) –(44) be written as

$$U=U_0+pU_1+p^2U_2+\ldots\ldots\ldots.$$

$$\phi=\phi_0+p\phi_1+p^2\phi_2+\ldots\ldots\ldots. \quad (45)$$

$$\psi=\psi_0+p\psi_1+p^2\psi_2+\ldots\ldots\ldots.$$

Substituting equation (45) into equations (42) – (44) and comparing the coefficients p^0, p^1, p^2 and p^3, the results are

$$p^0:\ \mathrm{Re}^{-1}U_0''-P_x=0 \quad (46)$$

$$p^0:\ \mathrm{Pr}^{-1}\phi_0''=0 \quad (47)$$

$$p^0:\ Sc^{-1}\psi_0''=0 \quad (48)$$

$$p^1:\ \mathrm{Re}^{-1}U_1''+nU_0+Gr_T\phi_0+Gr_T\psi_0=0 \quad (49)$$

$$p^1:\ \mathrm{Pr}^{-1}\phi_1''+(n-N)\phi_0=0 \quad (50)$$

$$p^1:\ Sc^{-1}\psi_1''+(n-k_0)\psi_0=0 \quad (51)$$

$$p^2:\ \mathrm{Re}^{-1}U_2''+nU_1+Gr_T\phi_1+Gr_T\psi_1=0 \quad (52)$$

$$p^2:\ \mathrm{Pr}^{-1}\phi_2''+(n-N)\phi_1=0 \quad (53)$$

$$p^2:\ Sc^{-1}\psi_2''+(n-k_0)\psi_1=0 \quad (54)$$

$$p^3:\ \mathrm{Re}^{-1}U_3''+nU_2+Gr_T\phi_2+Gr_T\psi_2=0 \quad (55)$$

$$p^3:\ \mathrm{Pr}^{-1}\phi_3''+(n-N)\phi_2=0 \quad (56)$$

$$p^3:\ Sc^{-1}\psi_3''+(n-k_0)\psi_2=0 \quad (57)$$

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with the modified boundary conditions

$$U_0=U_1=U_2=U_3=e^{nt}\ \text{at}\ y=0$$

$$\phi_0=\phi_1=\phi_2=\phi_3=e^{nt}\ \text{at}\ y=0$$

$$\psi_0 = \psi_1 = \psi_2 = \psi_3 = e^{nt} \text{ at } y = 0 \tag{58}$$

$$U_0 = U_1 = U_2 = U_3 = 0 \text{ at } y = e^{nt}$$

$$\phi_0 = \phi_1 = \phi_2 = \phi_3 = 0 \text{ at } y = e^{nt}$$

$$\psi_0 = \psi_1 = \psi_2 = \psi_3 = 0 \text{ at } y = e^{nt}$$

Solving equations (46) – (48) and imposing the appropriate boundary conditions from equation (58), the results are

$$U_0 = -\frac{1}{2}\mathrm{Re}\,P_x y^2 + \frac{1}{2}\mathrm{Re}\,P_x e^{nt} y - 1 + e^{nt} \tag{59}$$

$$\phi_0 = -y + e^{nt} \tag{60}$$

$$\psi_0 = -y + e^{nt} \tag{61}$$

Similarly, the solution to equations (49) – (51) after imposing the appropriate boundary conditions from equation (58) are

$$U_1 = -\frac{1}{2}\mathrm{Re}\,nU_0 y^2 - \frac{1}{2}\mathrm{Re}\,Gr_T\phi_0 y^2 - \frac{1}{2}\mathrm{Re}\,Gr_C\psi_0 y^2$$

$$+\frac{1}{2}\left(\mathrm{Re}\,nU_0 e^{nt} + \mathrm{Re}\,Gr_T\phi_0 e^{nt} + \mathrm{Re}\,Gr_C\psi_0 e^{nt} - 2\right)y + e^{nt} \tag{62}$$

$$\phi_1 = -\frac{1}{2}\Pr(n-N)\phi_0 y^2 + \left(\frac{1}{2}\Pr(n-N)\phi_0 e^{nt} - 1\right)y + e^{nt} \tag{63}$$

$$\psi_1 = -\frac{1}{2}Sc(n-k_0)\psi_0 y^2 + \left(\frac{1}{2}Sc(n-k_0)\psi_0 e^{nt} - 1\right)y + e^{nt} \tag{64}$$

Further, the solution of equations (52) – (54) and the use of the appropriate boundary conditions from equation (58) are respectively

$$U_2 = -\frac{1}{2}\mathrm{Re}\,nU_1 y^2 - \frac{1}{2}\mathrm{Re}\,Gr_T\phi_1 y^2 - \frac{1}{2}\mathrm{Re}\,Gr_C\psi_1 y^2$$

$$+\frac{1}{2}\left(\mathrm{Re}\,nU_1 e^{nt} + \mathrm{Re}\,Gr_T\phi_1 e^{nt} + \mathrm{Re}\,Gr_C\psi_1 e^{nt} - 2\right)y + e^{nt} \tag{65}$$

$$\phi_2 = -\frac{1}{2}\Pr(n-N)\phi_1 y^2 + \left(\frac{1}{2}\Pr(n-N)\phi_1 e^{nt} - 1\right)y + e^{nt} \tag{66}$$

$$\psi_2 = -\frac{1}{2}Sc(n-k_0)\psi_1 y^2 + \left(\frac{1}{2}Sc(n-k_0)\psi_1 e^{nt} - 1\right)y + e^{nt} \tag{67}$$

Finally, following the same procedure, the solution of equations (55) – (57) are

$$U_3 = -\frac{1}{2}\mathrm{Re}\,nU_2 y^2 - \frac{1}{2}\mathrm{Re}\,Gr_T\phi_2 y^2 - \frac{1}{2}\mathrm{Re}\,Gr_C\psi_2 y^2$$

$$+\frac{1}{2}\left(\mathrm{Re}\,nU_2 e^{nt} + \mathrm{Re}\,Gr_T\phi_2 e^{nt} + \mathrm{Re}\,Gr_C\psi_2 e^{nt} - 2\right)y + e^{nt} \tag{68}$$

$$\phi_3 = -\frac{1}{2}\Pr(n-N)\phi_2 y^2 + \left(\frac{1}{2}\Pr(n-N)\phi_2 e^{nt} - 1\right)y + e^{nt} \tag{69}$$

$$\psi_3 = -\frac{1}{2}Sc(n-k_0)\psi_2 y^2 + \left(\frac{1}{2}Sc(n-k_0)\psi_2 e^{nt} - 1\right)y + e^{nt} \tag{70}$$

Equations (58) – (69), give the expressions for the velocity, temperature and concentration as

$$U = U_0 + U_1 + U_2 + .U_3 \ldots\ldots\ldots \tag{71}$$

$$\phi = \phi_0 + \phi_1 + \phi_2 + \phi_3 .... \quad (72)$$

$$\psi = \psi_0 + \psi_1 + \psi_2 + \psi_3 .... \quad (73)$$

Equations (71) – (73) is put into equation (37) and the complete solution takes the form

$$u = u_0 + u_1 + u_2 + .u_3 .... \quad (74)$$

$$\theta = \theta_0 + \theta_1 + \theta_2 + \theta_3 .... \quad (75)$$

$$C = C_0 + C_1 + C_2 + C_3 .... \quad (76)$$

Skin friction, Nusselt number and Sherwood number

The Skin friction is obtained as

$$\tau = \left(\frac{du}{dy}\right)_{y=0} = \frac{1}{2}\mathrm{Re}\,P\left(e^{nt}\right)^4 - \frac{3}{2}e^{nt} + 3\left(e^{nt}\right)^2 + \frac{1}{2}\mathrm{Re}\,Gr_T\left(e^{nt}\right)^3 + \frac{1}{2}\mathrm{Re}\,Gr_C\left(e^{nt}\right)^3 - \frac{1}{2}\mathrm{Re}\,n\left(e^{nt}\right)^2 \quad (77)$$

The rate of heat transfer coefficient as

$$Nu = -\left(\frac{d\theta}{dy}\right)_{y=0} = 4 + \Pr(n-N)\left(e^{nt}\right)^2 + \frac{1}{4}(\Pr)^2(n-N)^2\left(e^{nt}\right)^3 + \frac{1}{4}(\Pr)^3(n-N)^3\left(e^{nt}\right)^4 \quad (78)$$

and the rate of mass transfer coefficient as

$$Sh = -\left(\frac{dC}{dy}\right)_{y=0} = 4 + Sc(n-k_0)\left(e^{nt}\right)^2 + \frac{1}{4}(Sc)^2(n-k_0)^2\left(e^{nt}\right)^3 + \frac{1}{4}(Sc)^3(n-k_0)^3\left(e^{nt}\right)^4 \quad (79)$$

3. RESULTS AND DISCUSSION

$$\mu_0 = 4\pi x10^{-7} N/A^2, \varepsilon_0 = 8.85x10^{-12} C^2/Nm^2, t = 1, n = 1, P = 1$$

$$\sigma(\Omega m)^{-1} = 2,4,6,8,10, \sigma^{-1}(\Omega m) = 2,4,6,8,10, N = 2.5,3.5,4.5,5.5,6.5$$

$$k_0 = 1.8,3.6,5.4,7.2,9.0, Gr_T = 1.5,2.5,3.5,4.5,5.5, Gr_C = 2.8,3.8,4.8,5.8,6.8$$

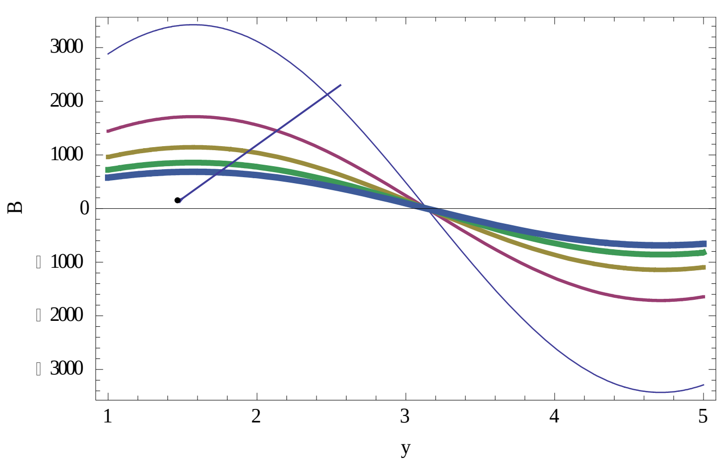

Figure 1 The dependence of Magnetic field strength on Coordinate with electrical conductivity term σ varying

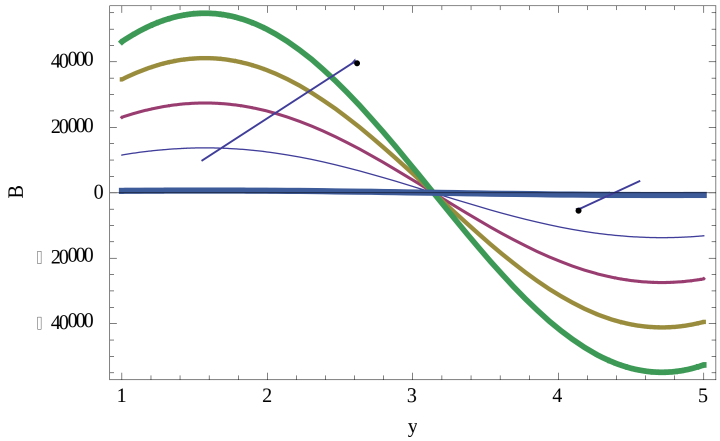

Figure 2 The dependence of Magnetic field strength on Coordinate with electrical resistivity term σ^{-1} varying

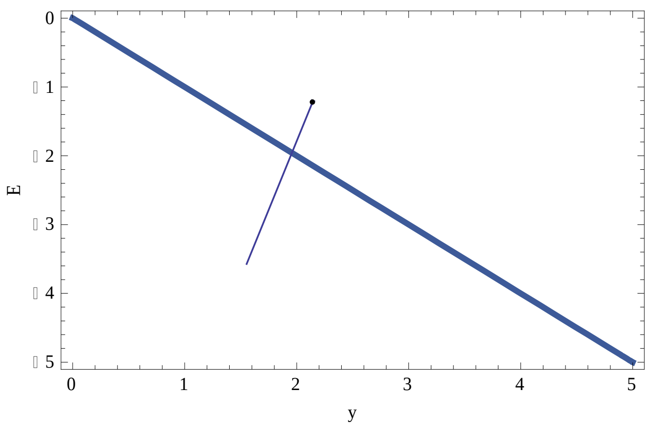

Figure 3 The dependence of Electric field strength on Coordinate with electrical conductivity term σ varying

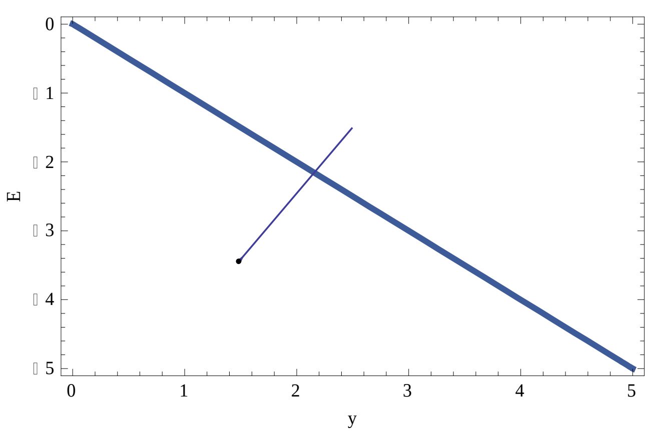

Figure 4 The dependence of Electric field strength on Coordinate with electrical resistivity term σ^{-1} varying

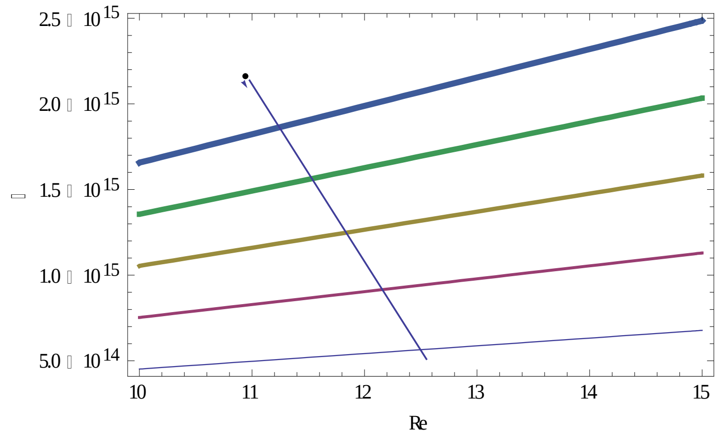

Figure 5 The dependence of Skin friction on Reynolds number with Grashof number due to Temperature Gr_T varying

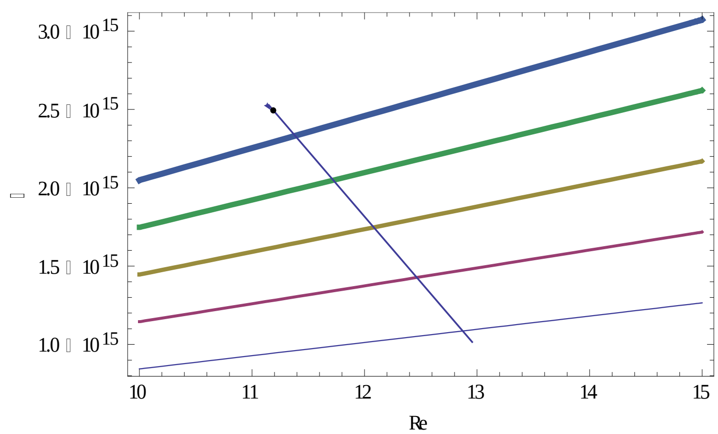

Figure 6 The dependence of Skin friction on Reynolds number with Grashof number due to concentration Gr_C varying

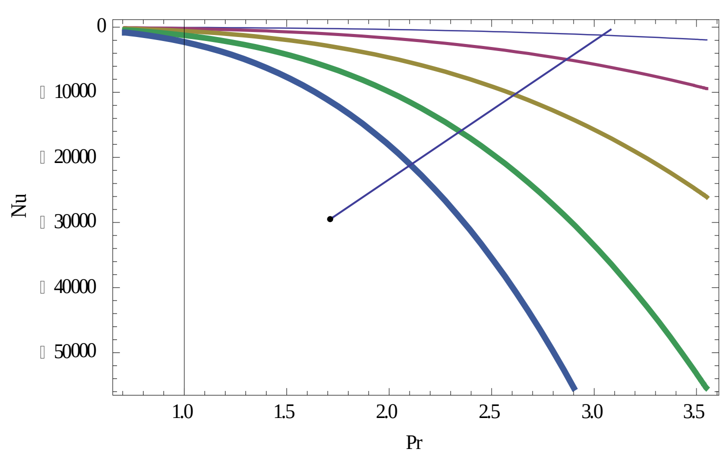

Figure 7 The dependence of mean Nusselt number on Prandtl number with Radiation N term varying

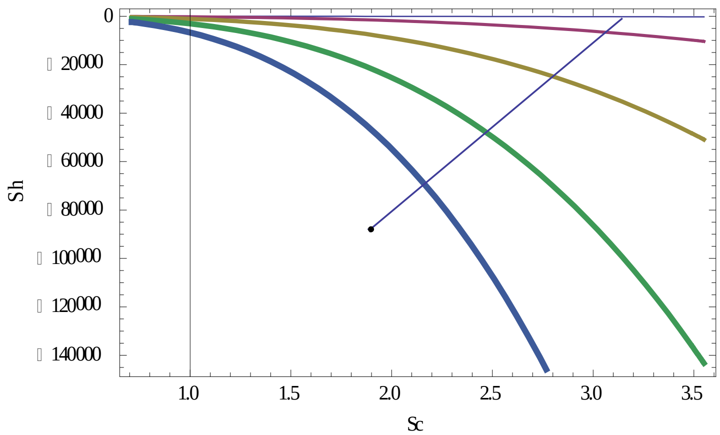

Figure 8 The dependence of Sherwood number on Schmidt number with chemical reaction k_0 term varying

Figure 1 shows a graphical relationship between the magnetic field strength and the space coordinate as the electrical conductivity of the fluid varies. The physical explanation of the graph is that, increase in electrical conductivity of the fluid corresponds to a decrease in the magnetic field strength. This observation appears to be the reverse case as depicted in Figure 2, which shows an increase in electrical resistivity of the fluid result in an increase in magnetic field strength and later dropped to zero. The effect of increasing electrical conductivity as shown in Figure 3 reveals that, the electric field intensity is increased and the reverse is the case with Fig4 as the electrical resistivity is increased. Comparison of Figure 1 and Figure 3 as well as Figure 2 and Figure 4 showed that the electric and magnetic fields have opposite effects, their reciprocals also and this laid credence to the findings of Symon [3]. The relationship between the skin friction and the Reynolds number as depicted in Figure 5, shows that increase in the Grashof number due to temperature correspond to an increase in the skin friction of the induced electrically conducting fluid and this observation is also the same with Grashof number due to concentration as depicted in Figure 6. A close observation of Figure 7 reveals that an increase in the radiation parameter, results in a decrease in the transport of heat coefficient considering the atmospheric Prandtl number of air. The explanation of this observation is that, an additional heat source due to flow of energy may lower the heat transfer coefficient of the fluid. Increase in chemical reaction which led to improved concentration of the fluid causes a decrease in the mass transfer of the fluid owing to slow motion as a result of increased velocity as shown in Figure 8.

4. CONCLUSION

When a fluid is introduced into an electromagnetic field, two major forces come into play as a result of the electrical conductivity of the fluid. The inclusion of radiation and chemical reaction terms to the existing non electromagnetic forces and to investigate the flow of the electromagnetic forces which have opposite effects are also interesting and conform to existing results. More study on the combined effect of electromagnetic forces and mechanical forces with the inclusion of other non electromagnetic forces of interest shall be our focus in the next study.

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